**Exam** - Chemical Systems and Equilibrium

Date\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Multiple Choice (Each one is 1pt)

1. (K) Which of the following statements about the equilibrium shown is always true?

N2O4(g) ⇋ 2NO2(g)

a)    At equilibrium, [N2O4] = [NO2]2

b)    At equilibrium, kf[N2O4] = kr[NO2]

c)    At equilibrium, [N2O4] = 2[NO2]

d)    At equilibrium, kf[N2O4] = kr[NO2]2

e)    None of the above statements is necessarily true

2. (K) Which of the following is/are false?

I) Reactant and product concentrations vary with time in a system that has reached equilibrium.

II) Dynamic equilibrium systems are static.

III) At equilibrium, the concentration of products is equal to the concentration of reactants.

IV) At equilibrium, the formation of the products is equal to the formation of the reactants.

a) I and II b) I, II and III c) II and III d) III only e) III and IV

3. (T/I) What is the correct equilibrium constant expression for the following reaction?

2NO2(g) ⇋ 2NO(g) + O2(g)

a) Kc = [O2]2[NO]/[NO2]2

b) Kc = [O2][NO]2/[NO2]2

c) Kc = [NO2]2/[NO]2[O2]

d) Kc = [NO2]2/[NO][O2]2

e) None of the above

4.  (A) Consider the equilibrium reaction:

3CIO-(aq) ⇋ CIO3-(aq) + 2CI-(aq)

The equilibrium constant of the reaction is Kc = 3.2 X 103. The following concentrations are present: [Cl-] = 0.50 mol/L; [ClO3-] = 0.32 mol/L; [ClO-] = 0.24 mol/L. Is the mixture at equilibrium and, if not, in which direction will reaction proceed?

a)    The system is at equilibrium.

b)    The system is not at equilibrium; reaction will proceed left to right.

c)    The system is not at equilibrium; reaction will proceed right to left.

d)    The system cannot reach equilibrium since the ClO3- and Cl- concentrations are not in the stoichiometric ratio.

e)    There is not enough information to tell.

5. (A) H2(g) + I2(g) ⇋ 2HI(g)

For the equilibrium above, Kc = 12.3. If a reaction mixture has [H2] = [I2] = [HI] = 3.21 X 10-3 mol/L, which one of the following statements is true?

a)    The concentration of HI will decrease as the system approaches equilibrium.

b)    The system is at equilibrium.

c)    The concentrations of H2 and I2 will increase as the system approaches equilibrium.

d)    The concentrations of H2 and I2 will decrease as the system approaches equilibrium.

e)    The system cannot reach equilibrium from the given starting conditions.

**Questions 6 and 7 refer to the equation below, which shows bromine dissolving in water.** Assume that the reaction is at equilibrium.

Br*2(aq)* + H2O*(l)* ⇋ H+1(aq) + Br-1(aq) + HBr(aq)

*red colorless*

6. (A) What observation would you expect if dilute acid such as hydrochloric acid were added to the system at equilibrium?

a) No observable change

b) The solution would become colorless

c) The solution would become red

d) The solution would become green

7. (A) Which one of the following would **not** cause the reaction to shift to the right?

a) Addition of Br- ions to the system

b) Decreasing the pH

c) Addition of Br2

d) Addition of H2O

e) Decreasing HBr

8. (T/I) Consider the reaction:

CH3Cl(aq) + OH-(aq) ⇋ CH3OH(aq) + Cl-(aq)

When the reaction is started with 0.10 moles of CH3Cl and 0.20 moles of OH-, 0.030 moles of CH3OH are obtained at equilibrium. Calculate the equilibrium constant.

a)    0.18

b)    0.076

c)    0.0009

d)    0.03

e)    2.5

9. (K) Consider the equilibrium:

2NH3(g) ⇋ N2(g) + 3H2(g)      ΔH°rxn = 92 kJ

Which of the following actions will cause a shift to the left (in favor of reactants)?

a)    removal of some H2

b)    addition of more NH3

c)    addition of gaseous Ar

d)    increasing the volume of the container

e)    lowering the temperature

10. (K) Which of the following is a correct description of the natural direction of a Brønsted-Lowry acid-base reaction?

a)    weaker acid + weaker base → stronger acid + stronger base

b)    weaker acid + stronger base → stronger acid + weaker base

c)    stronger acid + weaker base → weaker acid + stronger base

d)    stronger acid + stronger base → weaker acid + weaker base

e)    None of the above statements is always correct.

11. (T/I) Calculate the hydroxide ion concentration of a solution if its pH is 6.389.

a)    1.00 x 10-14 mol/L

b)    4.08 x 10-7 mol/L

c)    9.92 x 10-7 mol/L

d)    2.45 x 10-8 mol/L

e)    none of the above

12. (T/I) Calculate the acid-dissociation constant (Ka) for a weak acid (HA) if a 0.50M HA solution has a hydronium ion concentration of 3.0 x 10-4M.

a)    6.0 x 10-4

b)    5.0 x 10-6

c)    9.0 x 10-8

d)    6.0 x 10-6

e)    1.8 x 10-7

13. (A) Consider the titration of 0.1000M CH3COOH (Ka = 1.8 x 10-5) with 0.1000M NaOH. The pH at the equivalence point is

a)    between 2.0 and 4.0

b)    between 4.5 and 6.5

c)    approximately 7.0

d)    between 7.5 and 9.5

e)    between 11.0 and 13.0

14. (K) What is the solubility product constant expression (Ksp) for PbCl2?

a)    [Pb2+](2)[Cl-]

b)    [Pb2+] [Cl-]/2

c)    [Pb2+][Cl-]2/[PbCl2]

d)    [Pb2+] [Cl-]/[PbCl2]

e)    [Pb2+][Cl-]2

15. The solubility of AlF3 is 6.7g of AlF3 per liter of solution. What is the value of the solubility product constant for AlF3?

a)    1.9 x 10-2

b)    6.0 x 10-3

c)    1.1 x 10-3

d)    4.0 x 10-4

e)    4.1 x 10-5

Short Answer (Show all your work)

16. (4pts, T/I) When phosgene, a poisonous gas, is heated, it decomposes into carbon monoxide and chlorine:

COCl2(g) ⇋ CO(g)  +  Cl2(g)

When 2.00 mol of phosgene is put into an empty 1.00 L flask at 395°C and allowed to come to equilibrium, the final mixture contains 0.0398 mol of chlorine. What is the value of Kc?

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | COCl2(g) | ⇋ | CO(g) | + | Cl2(g) |
| I | 2.00 |  | 0 |  | 0  2pts |
| C | -0.0398 |  | +0.0398 |  | +0.0398 |
| E | 1.96 |  | 0.0398 |  | 0.0398 |

1pt

Kc = [CO] [Cl2] / [COCl2]

Kc = (0.0398) (0.0398) / (1.96)

Kc = 8.08x10-4

1pt

17. (1pt, T/I; 2pts C) For the following reaction

2Fe3+(aq)  +  Hg22+(aq)   ⇋   2Fe2+(aq)  +  2Hg2+(aq)         Kc = 9.1 x 10-6 at 298K

a)  Show that the reaction is not at equilibrium if the concentrations of the ions are: [Fe3+] = 0.20 M, [Hg22+] = 0.010 M, [Fe2+] = 0.010M and [Hg2+] = 0.025M?

Q = [Fe2+]2[Hg2+]2 / [Fe3+]2[Hg22+] = (0.01)2(0.025)2 / (0.2)2 (0.01)

1pt T/I

Q = 1.6 x 10-4

Therefore, since Q ≠ Kc the reaction is not at equilibrium

1pt C

           b)  In which direction will the reaction proceed to reach equilibrium? Explain.

To the right, since Q < Kc the reaction has more reactants than it needs or less products

1pt C

18. (4pts, C) The following system is at equilibrium in a closed container:

2SO2(g)  +  O2(g)  ⇋ 2SO3(g)                 ΔH = -198 kJ/mol

Explain the effects of the following on the equilibrium, and how the concentrations would change to restore equilibrium.

        a)  Decreasing the partial pressure of SO2 by removing some of it.

According to le Chatlier’s Principle, the equilibrium would shift to the left since sulfur dioxide is a reactant. The concentrations of oxygen and sulfur trioxide would decrease.

2pt C

       b)  Decreasing the temperature of the system

According to le Chatlier’s Principle, the equilibrium would shift to the right since the forward reaction is exothermic. The concentrations of oxygen and sulfur trioxide would increase.

2pt C

19. (4pts, A) The equilibrium mixture consisted of 0.600 mol of H2, 0.300 mol of CO2, 0.320 mol H2O and 0.700 mol of CO in a 1.00 L container.

H2(g) + CO2(g)  ⇋ CO(g) + H2O(g)

How many moles of water would have to be added to the above reaction vessel in order to increase the amount of CO2 to 0.500 mol when equilibrium is reached again? (Hint: Think very carefully about how you set up your ICE table. Pay attention to the validity of the assumptions that you might want to make.)

1pts

Kc = [CO][H2O] / [H2][CO2] = (0.7M)(0.32M) / (0.6M)(0.3M) = 1.24

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | H2(g) | + | CO2(g) | ⇋ | CO(g) | + | H2O(g) |
| I | 0.600 |  | 0.300 |  | 0.700 |  | 0.320+x  2pts |
| C | +0.200 |  | +0.200 |  | -0.200 |  | -0.200 |
| E | 0.800 |  | 0.500 |  | 0.500 |  | 0.120+x |

Kc = [CO][H2O] / [H2][CO2]

1.24 = (0.500)(0.120+x) / (0.800)(0.500)

1pts

x = 0.872 moles of O2

20. (3pts, K) Write out the reaction of ammonia (NH3) with water and indicate the members of the conjugate pairs.

1pt K

NH3 + H20 🡪 NH4+ + OH-

NH3 = conjugate base

1pt K

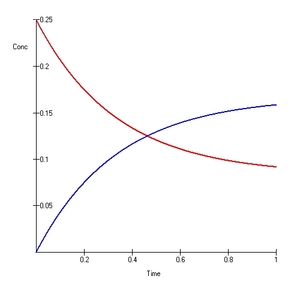
NH4+ = conjugate acid

H20 = conjugate acid

1pt K

OH- = conjugate base

Diagrams

21. Examine the graph provided on the

right and answer the following questions.

a) (1pt, C) Include appropriate labels

for the x- and y-axes.

1pt C

y-axis label: Time (s)

x-axis label: Concentration (M)

b) (1pt, C) Include a legend for the

graph which would provide an

appropriate label for each of the curves.

red line: [reactants]

1pt C

blue line: [products]

c) (1pt K; 2pts, C) In paragraph format,

describe what is happening in the

graph.

1pt C

Concentration of reactants is decreasing as concentration of products is increasing. The reactants are reacting together to form the products. A dynamic equilibrium is being established as indicated by the slopes of the lines approaching zero.

1pt K

1pt C

d) (2pts, A) Has the reaction reached equilibrium? Why or why not?

1pt A

Horizontal lines (flat) indicate the concentration of the reactants or products are unchanging. Since the lines are not fully horizontal, the system is not quite at equilibrium yet.

1pt A

e) (1pts A) If this experiment were

to be run again, how would you change

it to cause the reaction to reach

equilibrium more quickly?

Equilibrium can be reached more quickly by manipulating the factors that affect rate of reaction. This may involve manipulating temperature, concentration and pressure, physical state, and using a catalyst (Need one of these).

1pt A

22. Consider the titration of 25.00 mL of a 0.020 M ammonia solution (Kb = 1.3 x 10-8) with 0.100 M HCl

a)  (1pt K; 3pts, C) ***Sketch*** the graph (with proper labels) the titration curve for the reaction, indicating the approximate locations of:

i.    The half-neutralization point  
 ii.    The buffer region

iii.   The equivalence point

1pt K (Placing Point)

1pt C

(Graph)

1pt C

1pt C

b)  (4pts, T/I) What is the pH at the equivalence point?

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | NH3 | + | HCl | 🡪 | NH4Cl | + | H2O |
| Moles start | 0.0005 |  | 0.0005 |  | 0 |  | 1pts |
| Moles end | 0 |  | 0 |  | 0.0005 |  |  |
| Volume | 0.025L | + | 0.00005 | = | 0.025L |  |  |
| Concentration |  |  |  |  | 0.02 |  |  |
|  |  |  |  |  |  |  |  |

Kw = KaKb

1pts

Ka of ammonium = Kw / Kb = 1 x 10-14 / 1.3 x 10-8 = 7.7 x 10-7

Ka = [NH3][H+] / [NH4+] = (x)(x) / (0.02M) = 7.7 x 10-7

x2 = 1.54 x 10-8

1pts

x = [H+] = 1.24 x 10-4 M

1pts

pH = -log[H+] = 3.9